Geophysical Research Abstracts, Vol. 7, 02857, 2005
SRef-ID: 1607-7962/gra/EGU05-A-02857

Information loss in statistical prediction

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As has been pointed out previously by a number of investigators, it is possible to use information theory to quantify the rate at which information is lost in the statistical prediction of dynamical systems. In particular one can show that a very wide class of dynamical systems satisfy a monotonicity property for relative entropy. More precisely, relative entropy or prediction utility can be shown to either decline or be conserved in systems which satisfy a particular invariant transitional probability property. Most systems of practical interest in the geophysical context can be shown to satisfy this latter property. They can therefore be regarded as satisfying a generalized second law of thermodynamics with respect to predictions: Utility declines or is conserved as time increases. Interestingly many inviscid fluid systems also satisfy an additional relation known as the Liouville property and it is trivial to show in such systems that the relative (and absolute) entropy is actually conserved. When one makes a practical ensemble prediction with such systems however the relative entropy (or prediction utility) declines with time. The resolution of this paradox (analogous to Boltzmann's paradox in statistical mechanics) lies in the area of coarse graining. In other-words one can never (in a practical sense) calculate the entropy at infinite resolution and when it is calculated at finite or coarse resolution information on the finer unresolved scales is lost. In addition to presenting the theoretical ideas above at greater length, we study in detail this information loss process in a simple dynamical system (truncated Burgers equation) which has properties similar to the atmosphere.